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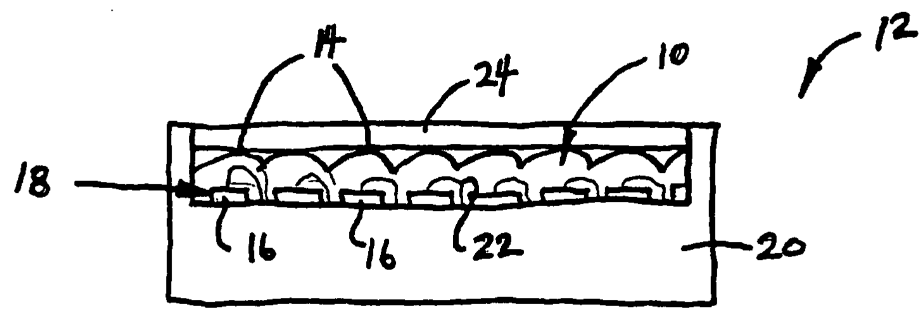

(57) **Abstract:** A lens array for collecting light from a light source is provided wherein the lens array is made of a curable gel that remains pliant after curing. The lens array may be used alone and without a hard epoxy matrix overcoat. The lens array may be used in an SOLID STATE LIGHT EMITTING DEVICE array that includes a lass window that covers the SOLID STATE LIGHT EMITTING DEVICE array and the lens array so that the lens array cannot be physically interfered with touched directly. An array of collecting microoptical lenses and/or prisms may be molded into the gel, and the gel lens used as an inexpensive array of lighting devices for the purpose of collecting and condensing the light from the SOLID STATE LIGHT EMITTING DEVICE array so that it is less dispersive.

WO 2005/043598 A2

USE OF POTTING GELS FOR FABRICATING MICROOPTIC ARRAYS

Inventors: Duwayne R. Anderson, Roland Jasmin, Jr. and Mark D. Owen

This invention claims the benefit of co-pending U.S. Provisional Application No. 60/516,053, entitled "Use of Potting Gels For Fabricating Microoptic Arrays," filed October 31, 2003, the entire disclosure of which is hereby incorporated by reference as if set forth in its entirety for all purposes

Background of the Invention

Solid state lighting devices such as, for example, light emitting diodes (LED's) are used for a number of applications. One type of such solid state lighting device is disclosed in International Patent Application No. PCT/US03/14625, filed May 28, 2003, entitled High Efficiency Solid-State Light Source And Methods Of Use And Manufacture, the details of which are hereby incorporated by reference. Some LED's are typically encapsulated in a soft gel that is then surrounded by a hard epoxy matrix. A hard epoxy cannot be used to encapsulate the LED because of the possibility that the sensitive bond wires would be pulled and damaged due to excessive stress when the assembly is heated and expands or contracts due to changes in temperature. The soft gel is used around the LED because it is very soft and compliant. Therefore, the gel will not pull off sensitive bond wires, or cause excessive stress. In prior art devices the hard epoxy matrix surrounding the gel is required because the gel is soft and can be damaged,

if touched. Additionally, the hard epoxy matrix is required because the gel is soft and can deform easily, so the hard epoxy matrix is used to hold shape in the gel. However, use of both the gel and the hard epoxy requires two potting steps – one step for applying the gel and the other step for applying the hard epoxy. This is undesirable since it increases the amount of time and cost required to build the assembly.

Examples of potting gels are those offered by Lightspan LLC, of Wareham, MA. Such potting materials may be used as an encapsulation material for increasing the amount of light output of the LED through index matching but have not been used in the prior art as forming molded lenses.

Another example of prior art gel is found in U.S. Pat. No. 6,541,800 (Barnett et al), the details of which are incorporated herein by reference. Barnett et al discloses a system comprising an LED package having an annular anode and a cathode coupled to the annular anode. An LED die is coupled to the cathode and the annular anode and a lens is coupled to the annular anode. A viscous material is located in a cavity defined by the lens, the cathode, and the annular anode. This patent discloses encapsulating an LED in a gel followed by encapsulating the gel in a solid cavity, which defines the lens surface. Thus, the gel has a dual function of an index matching material and as a collecting and directing microlens array.

Summary of the Invention

The present invention consists of the use of a gel that may be formed into an optical element such as a lens or lens array for collecting light from a light source. The

gel lens may be used without a hard epoxy matrix overcoat. In one embodiment, the gel is a curable gel that remains pliant after curing. The gel lens may be used in an LED array that may include a glass window that covers the LED array and the gel lens so that the gel lens cannot be physically damaged. Therefore, the glass window makes the hard epoxy matrix overcoat unnecessary. In another embodiment, the glass window functions as a lens serving to collect, collimate, and condense the light in addition to protecting the gel.

Furthermore, the gel lens in this invention collects, collimates, and condenses the light from a light source such as an LED array. Therefore, it is not necessary that the gel lens hold a firm shape. The gel lens must not permanently deform but it can wiggle. However, the gel lens need not hold traditional surface quality and tolerances because the application is one of light collection and not image formation. This eliminates the need for a rigid lens cavity/overcoat to hold the gel in place.

When used in this way, an array of collecting microoptical lenses and/or prisms may be molded into the gel, and the gel lens used as an inexpensive array of these devices for the purpose of collecting and condensing the light from the LED array so that it is less dispersive.

The lens of this invention may be used in a lens array for use with an LED array. The lens or lens array may be formed of a curable gel that remains pliant after curing for collecting light from a plurality of light sources that emit divergent light.

This invention further provides a lighting module for performing lighting applications that include an LED array including a plurality of LED's, and a lens array

including a plurality of lenses, wherein each lens in the lens array is associated with a respective LED to collect light emitted from the respective LED, the lens being formed of a curable gel, and a glass or transmissive cover for protecting the lens array.

This invention also provides a lens array and a method of making a lens array for use with a light source, comprising the steps of providing a mold to form a plurality of lenses, pouring a viscous gel into the mold, laying a circuit assembly containing an array of LED's onto the mold, curing the gel onto the circuit assembly, and removing the cured gel and the circuit assembly from the mold.

This invention further provides a lens array and a method of making a lens array for use with a light source, comprising the steps of, providing a mold to form a plurality of lenses, pouring a viscous gel into the mold, curing the gel, and removing the cured gel from the mold.

The lens array may be produced by a multi-step method. In one embodiment, the assembly can be formed by using a layer of gel to index match. A lens array may then be placed on top of the index matching gel. This incorporates a multi-step method of making a lens array in which an initial material is molded on the LED array and a subsequent material is used to form a lens-on-gel array. The material for the lens may be gels, epoxies, acrylics, urethanes, or other transmissive compounds. In another embodiment of the multi-step method, the gel may be formed into a gel-molded lens array and a second lens placed on top of the gel-molded lens array forming a lens-on-lens array. Again, the material for the lens may be gels, epoxies, acrylics, urethanes, or other transmissive compounds.

This invention further provides a method of making a lighting module, comprising the steps of, providing a mold to form a plurality of lenses, pouring a viscous gel into the mold, laying a circuit assembly containing an array of LED's onto the mold, curing the gel onto the circuit assembly, removing the cured gel and the circuit assembly from the mold, and providing a glass or other transmissive cover over the cured gel. The lighting module may be produced by the multi-step method described above.

These and other embodiments are described in more detail in the following detailed descriptions and the figures.

The foregoing is not intended to be an exhaustive list of embodiments and features of the present invention. Persons skilled in the art are capable of appreciating other embodiments and features from the following detailed description in conjunction with the drawings.

Brief Description of the Drawings

Figure 1 is a front view of a finished circuit assembly and cured gel lens with a glass window.

Figure 2 is a block diagram of the method steps for making a circuit assembly with a gel lens according to the present invention.

Figure 3 is a top view of one type of mold for use with this invention.

Figure 4 is an enlarged partial view of the mold of Fig. 3 taken along section line B-B.

Figure 5 is a partial sectional view of the mold of Fig. 4 taken along section line

C-C with a circuit assembly and gel.

Figure 6 is another top view of the mold of the present invention.

Figure 7 is a sectional view of the mold of Fig. 6 taken along section line A-A.

Figure 8 is a side view of the mold of Fig. 6.

Figure 9 is a perspective view of the mold of this invention

Figure 10 is another top view of the mold of this invention.

Figure 11 is a flow chart showing a multi-step method of forming a lens array.

Figure 12 is a flow chart showing another multi-step method of forming a lens array.

Figure 13 is a view of the arbor press with a positive mold assembly and a wax base plate assembly.

Figures 14, 14A, 14B, and 14C show various views of the positive mold assembly 72.

Figures 15, 15A, 15B, and 15C show various views of a positive mold plate holder 76 for use with arbor press 70.

Figures 16, 16A, 16B, 16C, and 16D show various views of a positive mold impression plate 78 of the positive mold assembly 72.

Figure 17 and 17A show various views of the wax base plate assembly 74.

Figures 18, 18A, and 18B show various views of a wax base plate carrier 80 of the wax base plate assembly 74.

Figures 19, 19A, and 19B show various views of a wax base plate 82 of the wax base plate assembly 74.

Detailed Description of the Invention

Representative embodiments of the present invention are shown in Figs. 1-20, wherein similar features share common reference numerals.

As best seen in Fig. 1, a lens array 10 for a light source such as, for example, a lighting module 12 is formed of a potting gel or other curable gel that remains pliant after curing. One type of gel suitable for use with this invention is encapsulation gel LS-6257 or encapsulation gel LS-3252 as manufactured and sold by Lightspan, LLC, of Wareham, MA. The gel is typically an epoxy-based gel but may be based on silicon or other type of gel. The gel may be optically transmissive for all wavelengths. However, the gel may be transmissive for certain wavelengths depending on the application. For example, for certain lighting applications the gel is transmissive within the wavelength range of about 360 nm to about 400 nm. The gel is used as an index matching material and as a lens to collect light from a light source that transmits divergent light. In one example, the gel, after curing, must remain transparent in the ultraviolet wavelength range and may be cured, for example, in the range of between 100 – 200 degrees C. The lens array 10 is formed with individual lenses 14 that are associated with a respective LED 16 in the LED array 18. The gel may be a curable gel but may be any material that is cured or otherwise transformed from a liquid or amorphous shape to a fixed state for an intended use.

As seen in Fig. 1, lighting module 12 includes circuit assembly 20 onto which an array of individual LED's 16 are connected by bonding wires 22. Lens array 10 covers

the LED's so the each LED 16 is associated with a lens 14. Lens array 10, after curing, is soft and pliant so that bonding wires 22 are not damaged due to stress or strain due to thermal expansion. A cover 24 made of, for example, glass covers lens array 18. Although Fig. 1 shows cover 24 touching lens array 10 it is not necessary that cover 24 touch lens array 10.

The lens array 10 is formed according to the steps set out if Fig. 2. A mold release is applied to the mold in step 26. The gel, in a viscous or liquid form, is first poured into a mold as seen in step 28. The liquid gel may have the viscosity of warm or hot honey. A circuit assembly containing a light source such as, for example, an array of LED's, put onto the mold so that each LED is associated with a lens as seen in step 30. The gel with the circuit assembly is then heated so that the gel cures in the mold and onto the circuit assembly as seen in step 32. The circuit assembly with the cured gel is then removed from the mold as seen in step 34. A cover is then placed on top of the cured gel so that the gel lens is sandwiched between the LED array and the cover as set out in step 36.

As seen most clearly in Fig. 3, the mold 38 may include, for example, over one thousand (1,000) indentations 40 to form the same number of lenses 14 in the lens array 10. The number of lenses may vary according to the application for which it will be used. The dimensions shown in Figs. 3-10 are in millimeters and are for illustrative purposes only and are not intended to limit this invention to the dimensions shown. The mold 38 may be metal, such as, for example, aluminum, or other material and may be of the type shown in Figs. 3-10.

As seen in Fig.5, mold 38 is filled with gel 42 and circuit assembly 20 containing LED's 16 are placed onto mold 38 as shown. Indentations 40 in mold 38 are shaped with curved surfaces 44 separated by a flat surface 46 so that the resulting lens adequately collects light from the LED. Circuit assembly 20 is placed onto mold 38 so that the resulting lens is centered about the LED and so that light from each side of LED 16 is projected in the respective curved surface 44. The shape of the resulting lens is determined by standard rules for finding the radius of curvature and distance of the point from which the radius extends for a plano-convex lens for each side of LED 44.

The lens array 10 collects, collimates, and condenses the diverse light emitted from the LED array 10. The lens array 10 collects the light so that it is condensed enough to perform certain non-imaging applications. One example of such an application is curing applications. Since the light does not need to be as precisely condensed as, for example, imaging applications that require collimated light, it is not necessary that the lens array 10 hold a firm shape. The lens array 10 must not be so pliant that is looses it's shape but it can be pliable enough to move without losing it's shape. However, the lens array 10 need not be configured with lenses having traditional surface quality and tolerances. This eliminates the need for a rigid lens cavity/overcoat to hold the gel in place. The glass cover 24 (Fig. 1) serves to protect the lens array 10.

Although cover 24 is described as glass this invention contemplates that the cover 24 could be made of a number of materials as long as the material is transmissive.

This invention also provides a lens array and a method of producing a micro lens array system according to a multi-step process in which one step incorporates index

matching and another step adds lenses forming a compound lens assembly. As seen in Figs. 11, 12, and 20a multi-step method of forming a lens array is provided. One skilled in the art may vary order of the steps.

In one embodiment of the multi-step process (Fig. 11), a layer of index matching gel is placed over the LED's in step 40. A molded optical device or lens is then placed on top of the gel layer in step 42. The lens may be molded from a variety of materials such as gels, epoxies, acrylics, urethanes, or other transmissive compounds.

In another embodiment of the multi-step process (Fig. 12), a UV epoxy is formed into an optical element such as a lens or lens array for collecting light from a light source to form a base-layer-lens. In the second step a second lens array or a top-layer-lens is placed on top of the base-layer-lens. More specifically, a mold release is added to a mold in step 50. In step 52, a viscous gel is poured into the mold. The circuit assembly is then placed onto the mold in step 54. In step 56, the gel is cured onto the circuit assembly. In step 58, the circuit assembly is removed with the cured gel from the mold. This forms the base-layer-lens. To form the top-layer-lens, a mold release is added to a mold in step 60 and in step 62, the top-layer-lens is formed using the steps 52-58. These steps may be performed as many times as needed. The base-layer-lens may be used without the top-layer-lens. More specifically, the base-layer-lens is molded onto the circuit assembly using index matching UV epoxy. The base-layer-lens covers the LEDs and wire bonds and, due to the index matching material, redirects divergent light transmitted from the LED to be substantially orthogonal to the assembly. There is a 15% - 25% improvement in the optical power measurement when measured at a distance of about 12mm above the

circuit assembly, when compared to a circuit assembly without index matching UV epoxy.

Once the base-layer-lens is cured in place the prefabricated top-layer-lens can be added for increased performance. The top-layer-lens is an array of micro-lenses shaped and spaced to collect light emitting from the individual LEDs on the circuit assembly. The prefabricated sheet of top-layer-lenses are aligned over the LEDs and bonded into place using a UV epoxy. The prefabricated sheet of top-layer-lenses can be molded using a UV epoxy or moldable glass. There is a 50% - 60% improvement in the optical power measurement when measured at a distance of about 12mm above the circuit assembly, when compared to a circuit assembly without index matching UV epoxy. The top-layer-lens is preferably a gel-molded lens and the bottom-layer-lens may be molded from a variety of material such as gels, epoxies, acrylics, urethanes, or other transmissive compounds.

One type of UV epoxy suitable for use with this invention is UV epoxy OG146 manufactured and sold by Epoxy Technology, Inc. of Billerica, MA. The UV epoxy is used as an index matching material and as a lens to collect the light from the light source that transmits divergent light.

This invention provides a method of making a base-layer-lens and a top-layer-lens array for use with a light source. The method includes the steps of providing a mold to form a plurality of lenses, pouring low viscous UV epoxy into the mold, curing the UV epoxy, removing the cured epoxy from the mold, aligning the top-layer-lens array, and curing the base-layer-lens and a top-layer-lens using a UV epoxy.

Figures 13 – 19 show tools and devices for making a lens assembly according to the steps of Fig. 20. Specifically, Fig. 13 shows an arbor press 70 with a positive mold assembly 72 and a wax base plate assembly 74. Figures 14, 14A, 14B, and 14C show various views of the positive mold assembly 72. Figures 15, 15A, 15B, and 15C show a positive mold plate holder 76 for use with arbor press 70. Figures 16, 16A, 16B, 16C, and 16D show a positive mold impression plate 78 of the positive mold assembly 72. Figure 17 and 17A show the wax base plate assembly 74. Figures 18, 18A, and 18B show a wax base plate carrier 80 of the wax base plate assembly 74. Figures 19, 19A, and 19B show a wax base plate 82 of the wax base plate assembly 74.

The steps for using the devices of Figs. 13-19B are seen in Fig. 20 in which a wax negative impression is made in step 90. The circuit assembly is placed onto the positive mold plate holder 76 in step 92. In step 94, the lens material is poured into the wax base plate assembly 74. In step 96, the tool set is closed and the material is polymerized. The mold is heated and wax evacuated in step 98. In step 100, the tool is opened and the potted assembly removed. In step 102 the wax residue is cleaned.

Persons skilled in the art will recognize that many modifications and variations are possible in the details, materials, and arrangements of the parts and actions which have been described and illustrated in order to explain the nature of this invention and that such modifications and variations do not depart from the spirit and scope of the teachings and claims contained therein.

While the inventor understands that claims are not a necessary component of a provisional patent application, and therefore has not included detailed claims, the

inventor reserves the right to claim, without limitation, at least the following subject matter.

WHAT IS CLAIMED:

1. An optical element for use with a solid state light emitting device array, comprising,

a plurality of optical elements formed of a material that remains pliant after curing for collecting light from a plurality of light sources that emit divergent light.

3. The lens array of claim 1, wherein each lens in the lens array is associated with a respective solid state light emitting device in the array.

4. A lighting module, comprising,

a solid state light emitting device array including a plurality of solid state light emitting devices,

a lens array including a plurality of lenses, wherein each lens in the lens array is associated with a respective solid state light emitting device to collect light emitted from the respective solid state light emitting device, the lens being formed of a curable gel, and

a cover for protecting the lens array.

5. A method of making a lens array for use with a light source, comprising the steps of,

providing a mold to form a plurality of lenses,

pouring a gel material into the mold,

laying a circuit assembly containing an array of solid state light emitting devices onto the mold,

curing the gel onto the circuit assembly, and

removing the cured gel and the circuit assembly from the mold.

6. A method of making a lens array for use with a light source, comprising the steps of,

providing a mold to form a plurality of lenses,

pouring a viscous gel into the mold,

curing the gel, and

removing the cured gel from the mold.

7. A method of making a lighting module, comprising the steps of,

providing a mold to form a plurality of lenses,

pouring a viscous gel into the mold,

laying a circuit assembly containing an array of solid state light emitting devices onto the mold,

curing the gel onto the circuit assembly,

removing the cured gel and the circuit assembly from the mold, and

providing a transmissive cover over the cured gel.

8. A mold for making a lens array, comprising,

a body having plural indentations, each indentation corresponding to a lens in the lens array, each indentation having a center and offset curved surfaces symmetrically located about the center.

9. A method of making a lens array, comprising the steps of,

molding a gel of at least one solid state light emitting device to form an index matching gel layer, and

molding an optical device to be placed on top of the gel layer.

10. A method of making a lens array, comprising the steps of,

providing a mold to form a plurality of lenses,

pouring a viscous gel into the mold,

laying a circuit assembly containing an array of solid state light emitting devices onto the mold,

curing the gel onto the circuit assembly,

removing the cured gel and the circuit assembly forming a first optical device from the mold ,

molding at least a second optical device using the steps to make the first optical device, and

placing the second optical device on the first optical device.

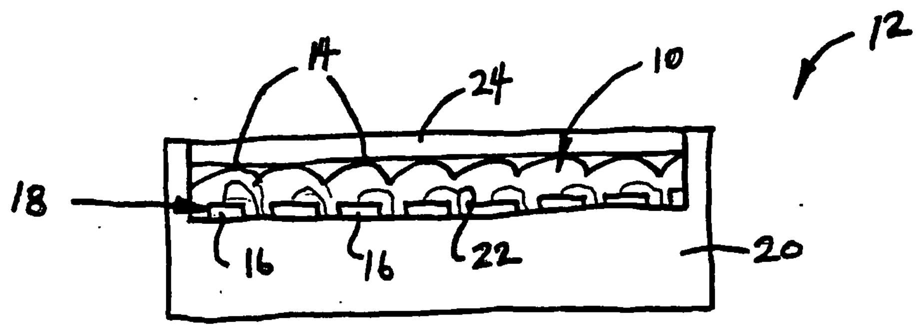

FIG. 1

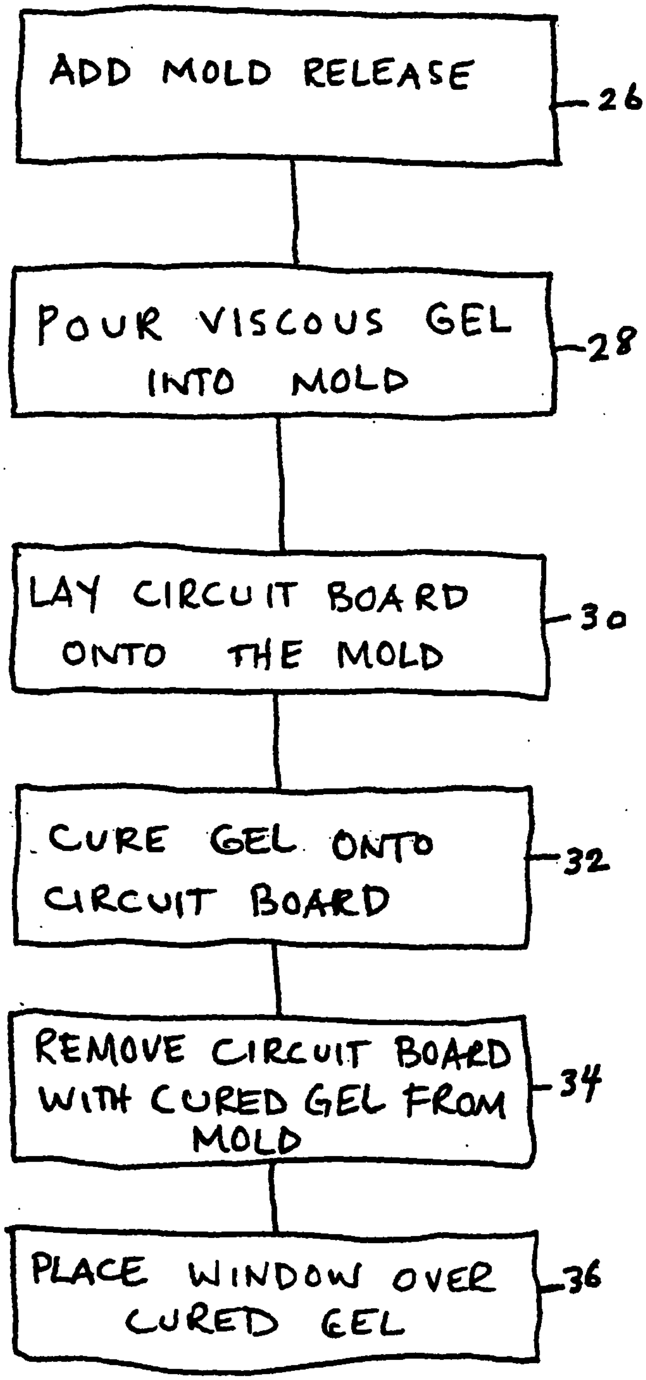
ADD MOLD RELEASE
26
POUR VISCOUS GEL INTO MOLD
28
LAY CIRCUIT BOARD ONTO THE MOLD
30
CURE GEL ONTO CIRCUIT BOARD
32
REMOVE CIRCUIT BOARD WITH CURED GEL FROM MOLD
34
PLACE WINDOW OVER CURED GEL
36

FIG. 2

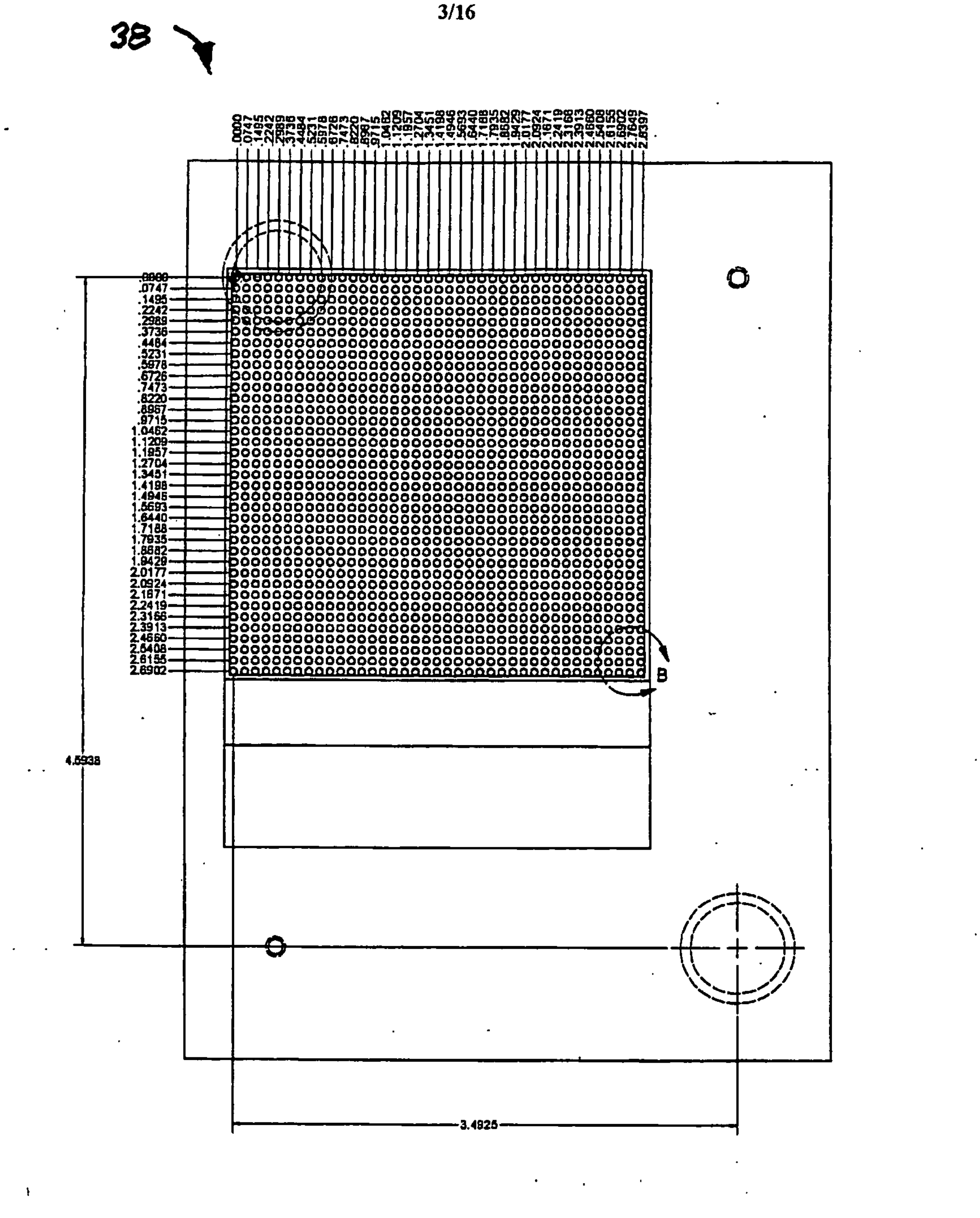
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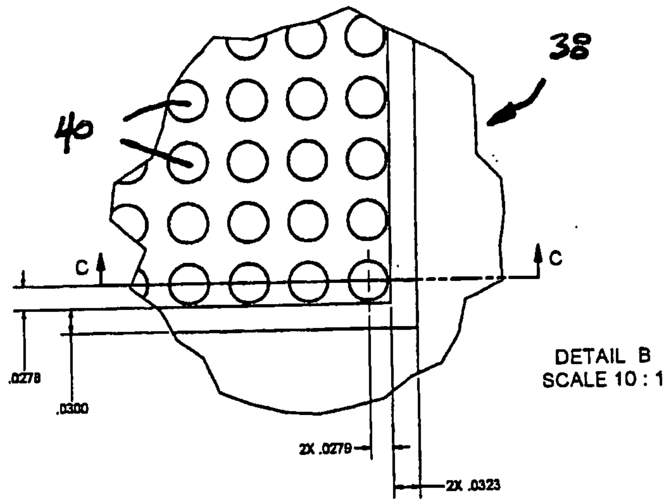
FIG. 3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40
C
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.0278
.0300
2X .0279
2X .0323
DETAIL B
SCALE 10 : 1

FIG. 4

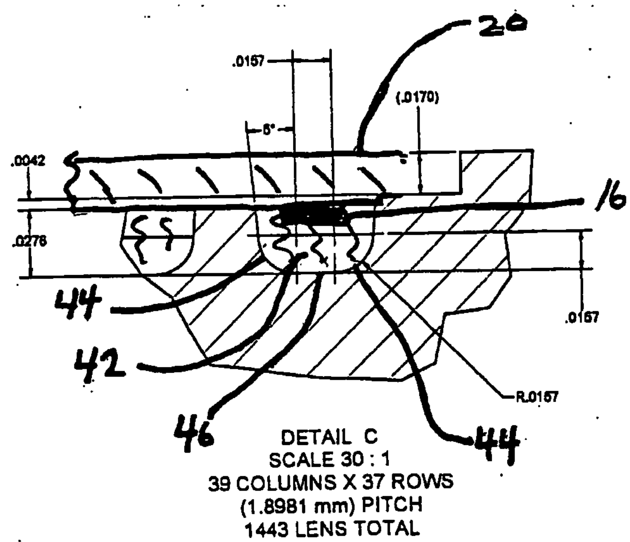
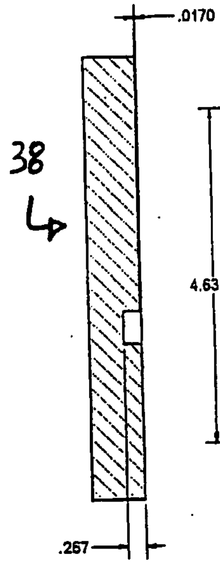

20
.0157
(.0170)
5°
.0042
16
.0278
.0157
44
42
R.0157
46
44
DETAIL C
SCALE 30 : 1
39 COLUMNS X 37 ROWS
(1.8981 mm) PITCH
1443 LENS TOTAL

FIG. 5



SECTION A-A

FIG. 7

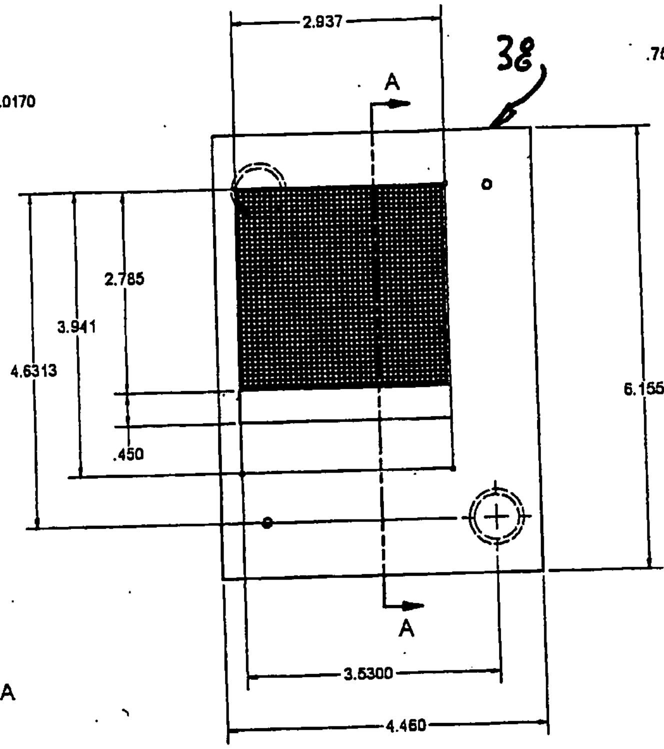


FIG. 6

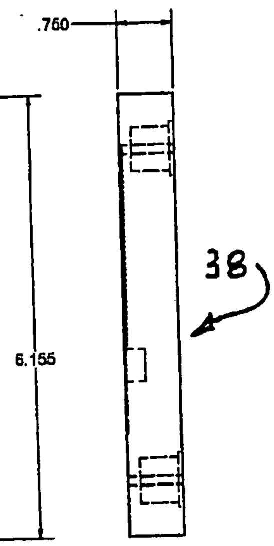


FIG. 8

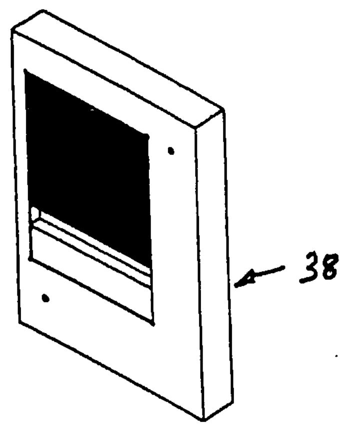

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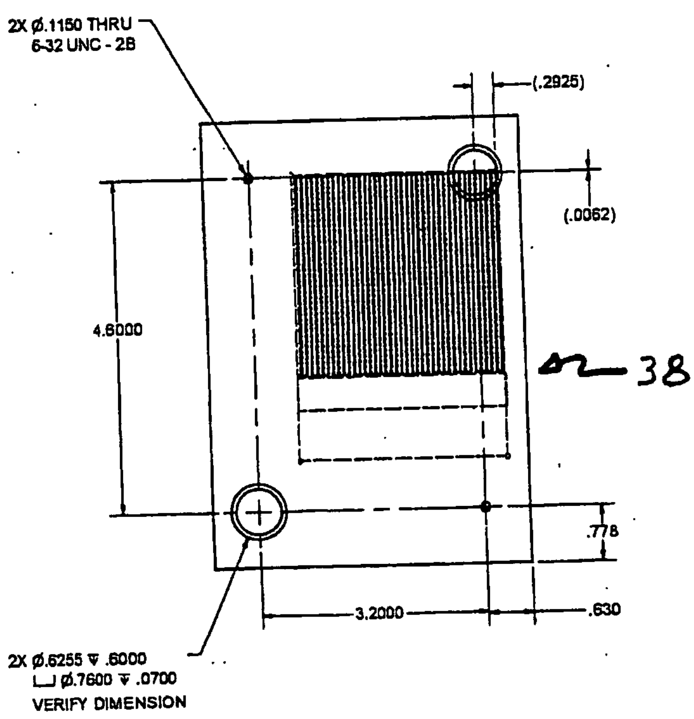
FIG. 9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(.0062)
4.6000
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3.2000
.630
2X Ø.6255 ▽ .6000
⌴ Ø.7600 ▽ .0700
VERIFY DIMENSION

FIG. 10

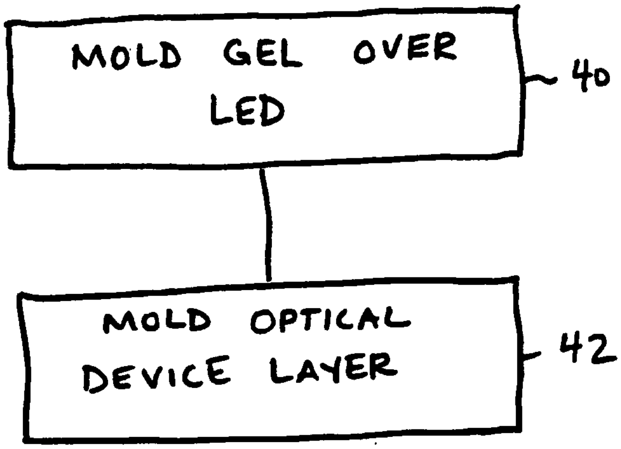


FIG. 11

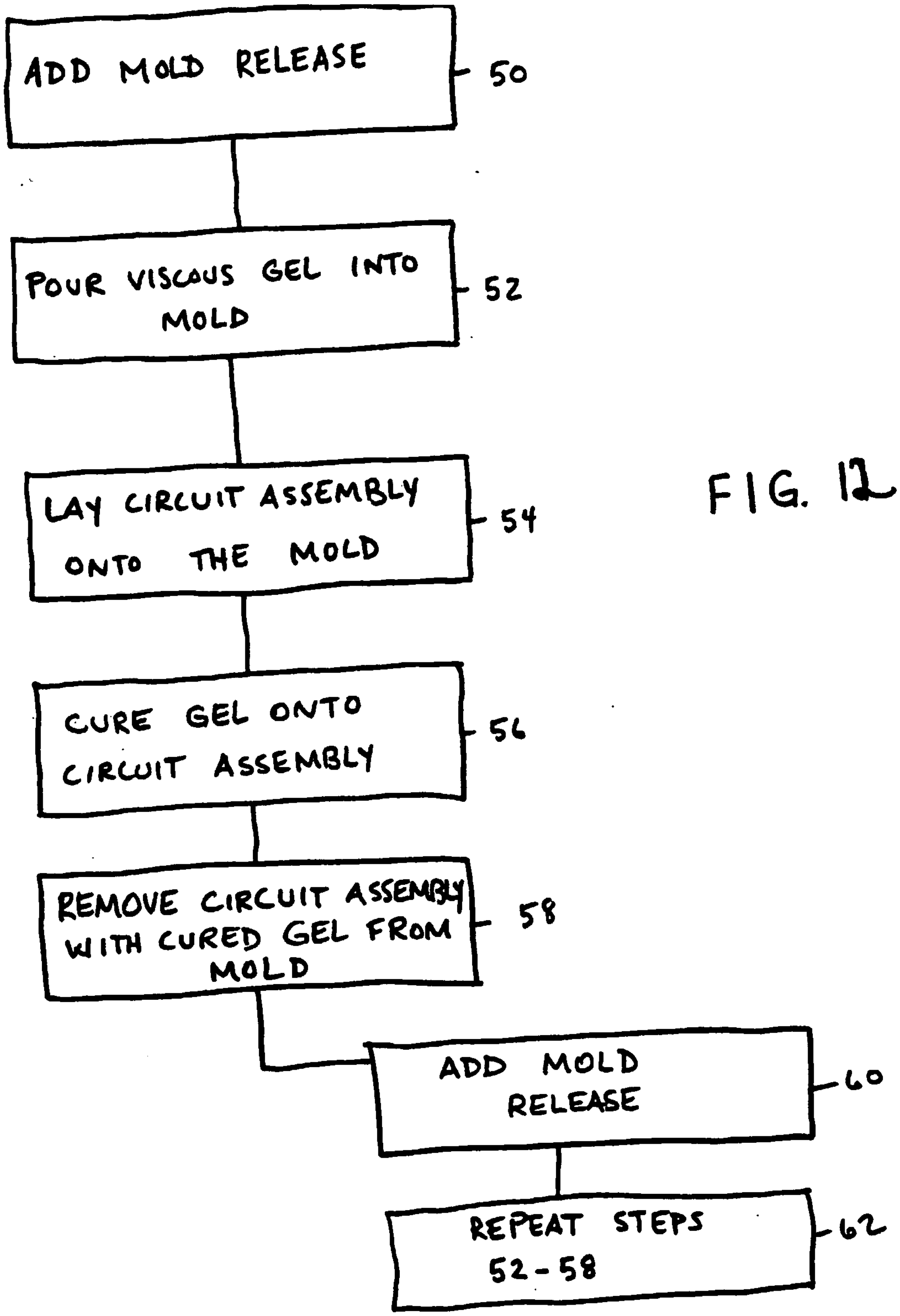

ADD MOLD RELEASE
50
POUR VISCOUS GEL INTO MOLD
52
LAY CIRCUIT ASSEMBLY ONTO THE MOLD
54
CURE GEL ONTO CIRCUIT ASSEMBLY
56
REMOVE CIRCUIT ASSEMBLY WITH CURED GEL FROM MOLD
58
ADD MOLD RELEASE
60
REPEAT STEPS 52-58
62

FIG. 12

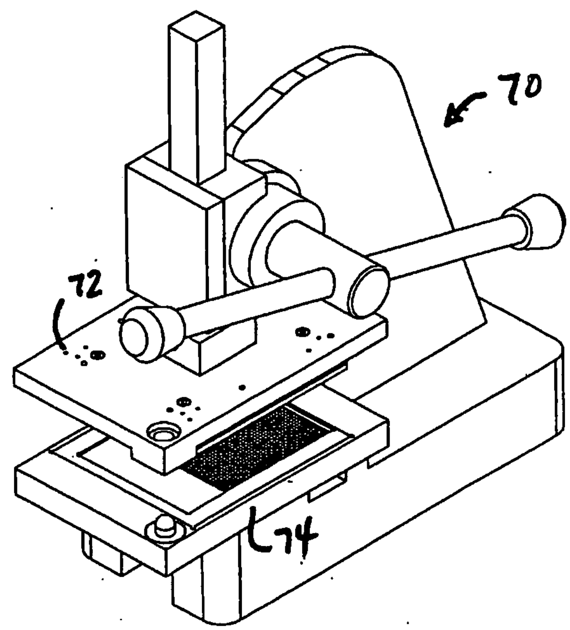


FIG. 13

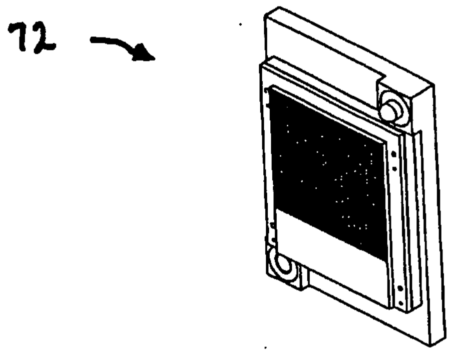


FIG. 14

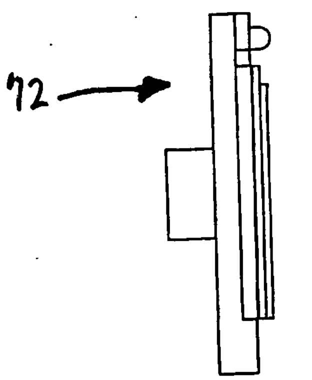


FIG. 14C

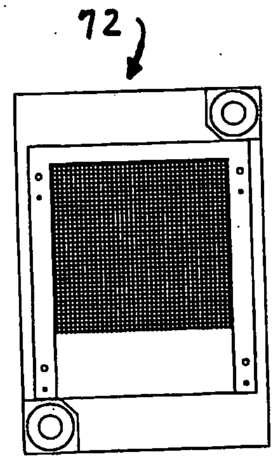
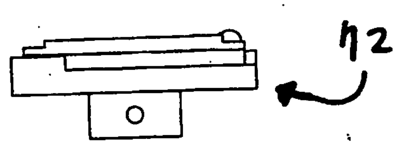


FIG. 14A

FIG. 14B



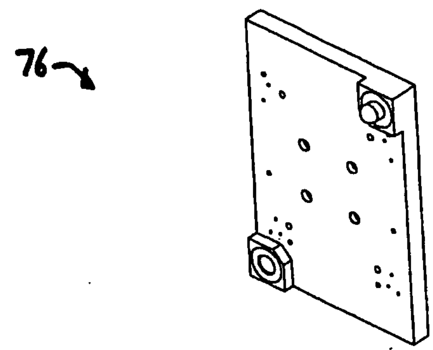


FIG. 15

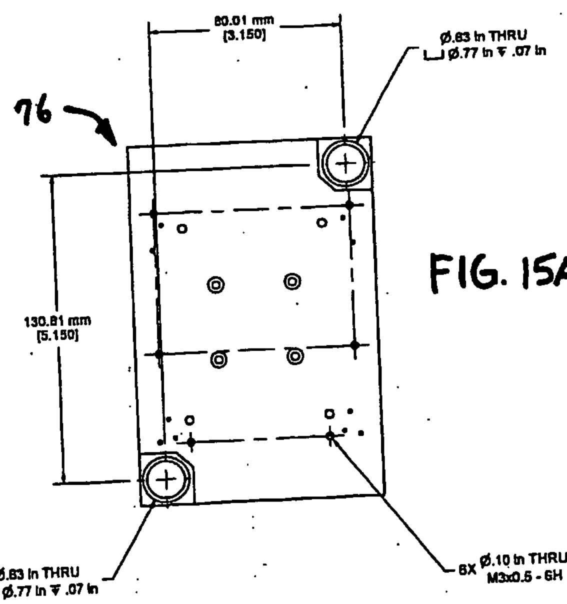


FIG. 15A

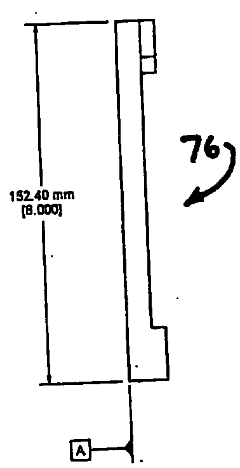


FIG. 15B

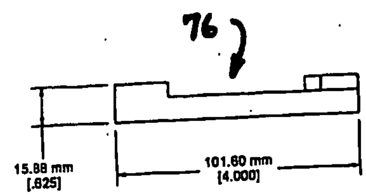
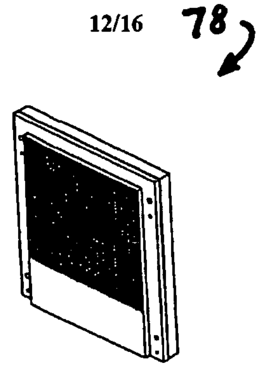


FIG. 15C

FIG. 16



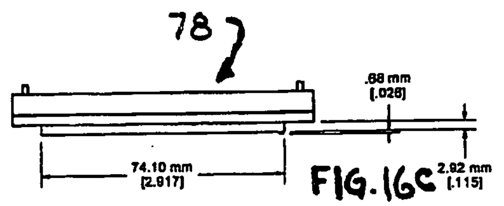


FIG. 16C

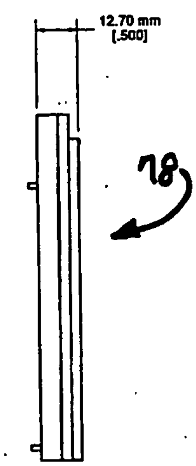


FIG. 16D

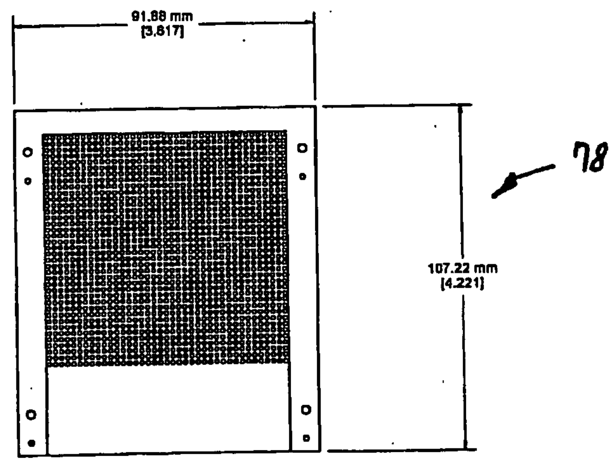


FIG. 16A

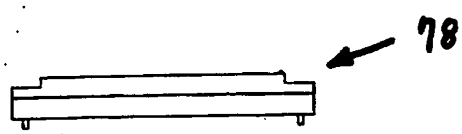


FIG. 16B

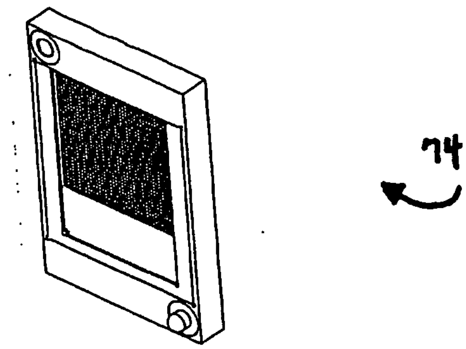


FIG. 17

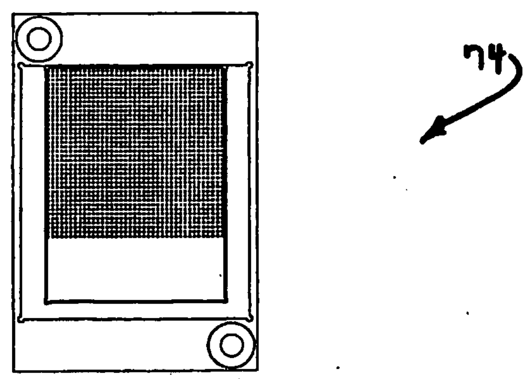


FIG. 17A

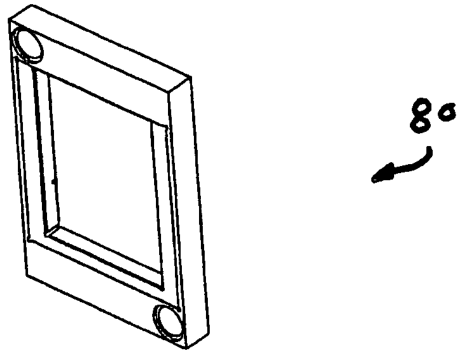


FIG. 18

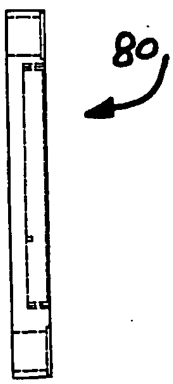


FIG. 18A

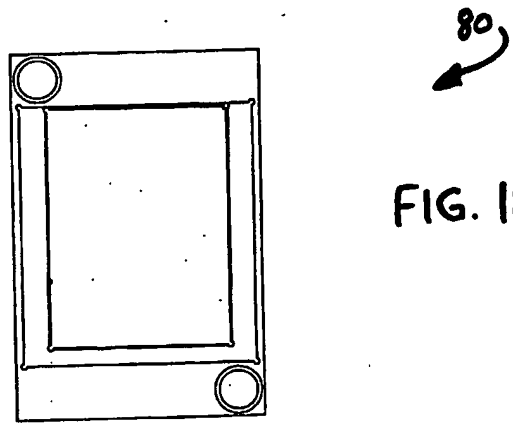


FIG. 18B

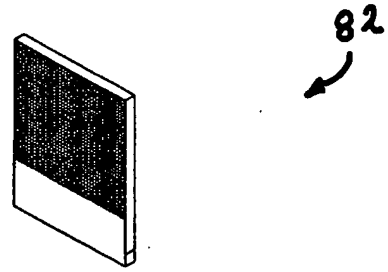


FIG. 19

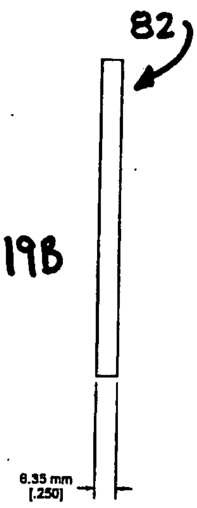


FIG. 19B

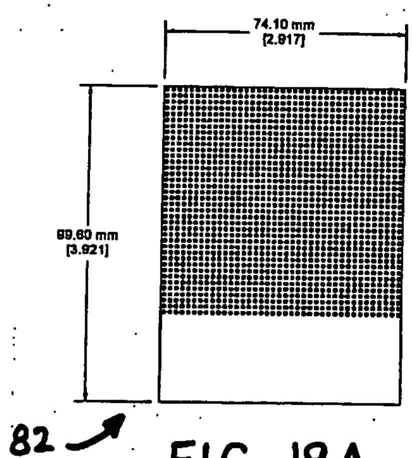


FIG. 19A

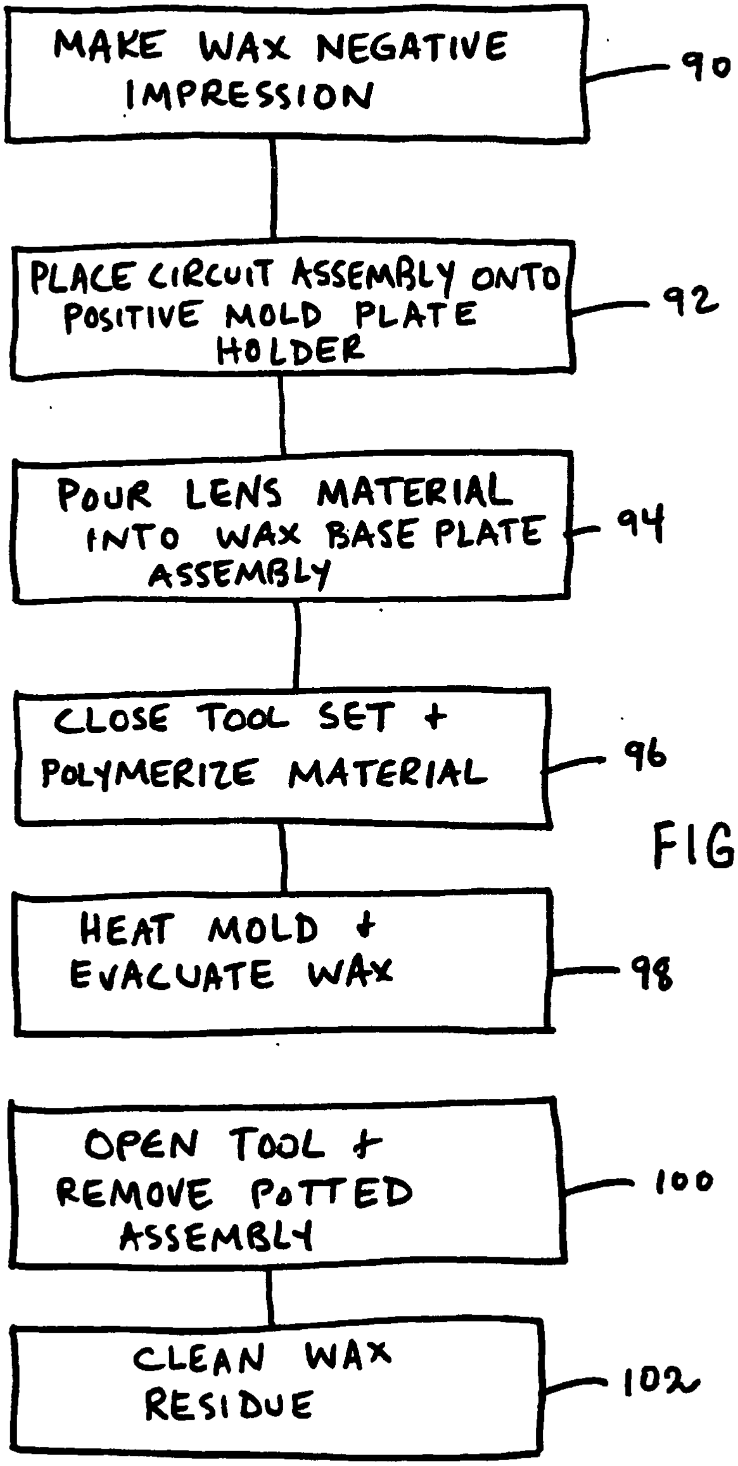

MAKE WAX NEGATIVE IMPRESSION
90
PLACE CIRCUIT ASSEMBLY ONTO POSITIVE MOLD PLATE HOLDER
92
POUR LENS MATERIAL INTO WAX BASE PLATE ASSEMBLY
94
CLOSE TOOL SET + POLYMERIZE MATERIAL
96
HEAT MOLD + EVACUATE WAX
98
OPEN TOOL + REMOVE POTTED ASSEMBLY
100
CLEAN WAX RESIDUE
102

FIG. 20